VEGETATION OF THE ALABAMA HILLS REGION, INYO COUNTY, CALIFORNIA

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ABSTRACT

All woody and succulent vegetation in the arid Alabama Hills region was sampled, using 24 0.07 ha plots regularly placed over an area of 80 km^2. Density and canopy volume were measured and the data treated by polar ordination. Intensity of grazing, geologic substrate, and topographic roughness were environmental features that correlated with local variation in the regional vegetation type. Overall, the vegetation is transitional between Great Basin sagebrush steppe and Mojave Desert creosote bush scrub. It is similar to the *Grayia-Lycium* community that has been described for (and thought to be restricted to) southern Nevada by Beatley (1975), except that *Atriplex polycarpa, Eriogonum fasciculatum* subsp. *polifolium,* and *Haplopappus cooperi* are additional codominants. The senior author anticipates repeated sampling on these permanently located plots every 5 years.

The Great Basin area of California has received so little phytosociological attention that it has been called a "forgotten ecological province" (Young et al. 1977); yet, it covers about 2% of the state's area. Major communities include sagebrush scrub or steppe, shadscale scrub, and blackbrush scrub. The southern portion of this province is particularly complex where it abuts the Mojave Desert (Randall 1972, Vasek and Barbour 1977, Thorne et al. 1981, Taylor, unpub. BLM reports). It was our objective to begin a long-term study of vegetation dynamics in this southern region. This paper presents only initial data on the range of community variation, which may be due to such factors as grazing, geologic substrate, slope aspect, and topographic or soil surface roughness.

METHODS

Study area. The area selected for sampling includes all of the Alabama Hills and part of a bajada just to the west, altogether covering an area of about 30 sections (80 km^2). The Alabama Hills extend about 15 km along a southeast-to-northwest axis that centers on 36°37′N and 118°05′W, only 2–3 km west of Lone Pine, Inyo County. They rise from a basal elevation of 1160 m to peaks of 1700 m and are of Jurassic age. The westerly $^4/_5$ is granitic and the easterly $^1/_5$ is metavolcanic.

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Sampling on the adjacent bajada to the west centered on the 1560 m contour. The bajada is composed of Pleistocene and Recent granitic alluvium from the east flank of the Sierra Nevada Mountains. Soils tend to be coarse-textured entisols, inceptisols, or aridisols; Alabama Hills sites in addition may be strewn with large boulders on the surface.

The nearest weather station is at Independence, 26 km north of Lone Pine at an elevation of 1200 m (Anonymous 1981). Mean annual precipitation is 138 mm, 70% of which falls during the fall and early winter (October through February). Mean temperatures are: January, 6°C; July, 27°C; annual, 16°C. There are more than 170 frost-free days, and temperatures below −10°C are rare. Maximum summer temperatures are rarely above 42°C.

Sampling procedures. A total of 29 potential sampling locations were established at the intersections of section lines, thus placing them systematically 1 mile (1.6 km) apart in a grid pattern. In this paper, we summarize data from 24 of those locations, excluding five because of highly atypical situations: sites of road and residence construction, seeps and springs, altered by type conversion activities. Each location was a circle 30.5 m in diameter (0.07 ha in area). Within each circle, all woody species and cacti were counted, and canopy dimensions (length, width, height) of every individual were measured. Canopy volumes were later calculated, using a circular cone as a model (length and width were averaged to estimate the circle's diameter). Although a circular cone does not approximate the shape of all canopies, we feel justified, at this initial stage of the study, to use it uniformly for all species. Presence of some herbaceous perennials (e.g., *Stipa*) was noted but not quantified; annuals and perennial seedlings were ignored due to variation in time of sampling, which extended throughout 1980. The sites are permanently marked so the senior author can repeat the measurements every 5 years.

Notes were made on the intensity of cattle grazing, based on a knowledge of land use history and field evidence (but see Results and Discussion section), soil surface roughness (extent of boulders, topographic diversity), presence of lichens and moss, soil surface texture, slope angle and aspect, presence of daily or seasonal shade, geologic substrate (granitic or metavolcanic), extent of rodent activity, and plant phenology. Plant nomenclature follows Munz and Keck (1959). A more complete species list and quantification of field data can be obtained from the senior author.

Data analyses. Summary tables were prepared for each site, listing absolute density, relative density, absolute canopy volume, and relative canopy volume for each species. We believe that canopy volume can convey a picture of overstory dominance superior to that from percent canopy cover.

Polar ordination of the sites was performed by a computer program (ORDIFLEX release B, program CEP-25B, in the Cornell Ecology Programs series) provided by H. G. Gauch, Jr., of Cornell University. The program calculated indices of similarity (IS) for every pair of sites, weighting species presence by absolute density with Motyka's modification of Sorensen's formula (Mueller-Dombois and Ellenberg 1974):

$$IS = \frac{(2)(M_{min})}{M_{site\ 1} + M_{site\ 2}}$$

M is absolute density for any species; M_{min} is the minimum density of every species common in both sites, summed for all species, $M_{site\ 1}$ is the sum of all species densities in site 1; $M_{site\ 2}$ is the sum of all species densities in site 2. Rare species, occurring on fewer than three sites, were omitted from the analysis. The program then used the IS values to calculate an index of difference (ID) between every pair of sites, where: ID = 1.0 − IS. A two-dimensional polar ordination was performed on the matrix of ID values, using automatic endpoint selection for both axes.

We recognize that polar ordination is not universally considered to be the best vegetation analysis technique (see for example, Whittaker 1978). However, it is a simple, straightforward means of illustrating stand relationships; its biases and distortions are not critical at this initial stage of vegetation description.

Results and Discussion

General vegetation. Although the Alabama Hills region has been mapped as a sagebrush scrub or steppe by both Küchler (1977) and Matyas and Parker (1979), the actual vegetation is something quite different. According to Küchler (1977) and the Regional Ecology Group (1981), California sagebrush vegetation is moderately open (about 15% cover), dominated by evergreen shrubs up to 1 m tall (in particular by *Artemisia tridentata*), with an admixture of deciduous shrubs and below them a seasonal 5–15% cover by graminoids, forbs, and winter annuals. Cacti are uncommon.

Alabama Hills vegetation, by contrast, is dominated by a collection of partly or completely drought-deciduous sub-shrubs less than 0.5 m high. *Artemisia tridentata* was found on only five of the 24 sites. There were four species of cactus, and these occurred in 15 of the 24 sites. Altogether, 43 woody and succulent taxa were recorded, a higher species richness than one would expect from sagebrush scrub or steppe. Table 1 summarizes the eight leading dominants, based on relative canopy volume averaged over all 24 sites. Although *Atriplex polycarpa* and *A. confertifolia* have the highest values in that list, they are not dramatically larger than the next several species on the list; thus one could conclude that this regional community exhibits dominance by at least a handful of species with 60–70% constancy (presence).

TABLE 1. LEADING DOMINANTS (BASED ON PERCENT RELATIVE CANOPY VOLUME) AVERAGED FOR ALL 24 STANDS. Species are listed in descending order, down to an arbitrary limit of 6% relative canopy volume. For comparative purposes, the *Grayia-Lycium* transitional community of southern Nevada (Rickard and Beatley 1965) has been summarized in the right-hand column; those data are in percent relative cover.

Alabama Hills			*Grayia-Lycium*	
Species	Volume	Stands present	Cover	Species
Atriplex polycarpa	13	15	—	
Atriplex confertifolia	12	15	5	*Atriplex confertifolia*
Ephedra nevadensis	9	19	4	*Ephedra nevadensis*
Eriogonum fasciculatum	9	15	—	
Grayia spinosa	8	17	39	*Grayia spinosa*
Lycium andersonii	7	18	19	*Lycium andersonii*
Haplopappus cooperi	6	11	—	
Hymenoclea salsola	6	19	2	*Hymenoclea salsola*
Others, to match *Grayia-Lycium* associates:				
Eurotia lanata	1	13	11	*Eurotia lanata*
Atriplex canescens	<1	2	4	*Atriplex canescens*
Tetradymia axillaris	1	2	4	*Tetradymia axillaris*
	—	—	3	*Acamptopappus shockleyi*
Coleogyne ramosissima	<1	2	3	*Coleogyne ramosissima*
Artemisia spinescens	1	14	3	*Artemisia spinescens*

If this regional community does not fit well into the sagebrush scrub category, neither does it fit well into other Great Basin Californian types, such as blackbrush scrub, shadscale scrub, or saltbush scrub, as recently reviewed by Vasek and Barbour (1977). Blackbrush (*Coleogyne ramosissima*), shadscale (*Atriplex confertifolia*), and saltbush or allscale (*Atriplex polycarpa*) are all in the Alabama Hills (Table 1), but none shows the dominance it characteristically exhibits in its own type. Shadscale stands sampled by Billings (1949) in southern Nevada exhibited 44% average relative canopy cover by *Atriplex confertifolia* (range of 11–98%); this contrasts with only 12% relative canopy volume of shadscale in our stands. Furthermore, the second most abundant shrub in the shadscale vegetation sampled by Billings was *Sarcobatus baileyi* (28% relative cover), which was absent from the Alabama Hills. The third most abundant shadscale scrub species was *Artemisia spinescens* (17% relative cover), which was much less important in the Alabama Hills (1% relative canopy volume, Table 1).

Saltbush scrub in California (Vasek and Barbour 1977) typically not only contains *Atriplex polycarpa* and *A. confertifolia,* present in the Alabama Hills, but usually also the more narrowly halophytic succulents *Allenrolfea occidentalis, Nitrophila occidentalis, Salicornia subterminalis, Suaeda* species, and *Sarcobatus vermiculatus,* all of which are absent from Alabama Hills study sites. Saltbush scrub is usually an edaphically defined community, on saline soils, and the mere presence of *Atriplex* species in the Alabama Hills is not sufficient to place our sites within that community.

Even though many species are shared with the blackbrush community (e.g., *Artemisia tridentata, Atriplex confertifolia, Dalea fremontii, Ephedra nevadensis, Eriogonum fasciculatum, Gutierrezia microcephala*; see Cronquist et al. 1972), *Coleogyne* here had less than 1% relative canopy volume, far from the overwhelming dominant it usually is in a typical blackbrush community. Neither does this community closely resemble the mixed desert scrub described by Thorne et al. (1981) and Randall (1972) for the eastern Mojave Desert of California. That mixed community shares only $^1/_3$ of its genera with our vegetation; it appears to be floristically much richer, it lacks clear dominants, and it contains a greater diversity of life forms, in comparison with our vegetation. A few of our most bouldery sites (C, O, and Q are described in the Ordination section of this paper) do resemble this mixed scrub in habitat and composition, but the majority of our sites differ from it.

In our opinion, the regional Alabama Hills vegetation can best be described as a variant of the *Grayia spinosa-Lycium andersonii* community described in southern Nevada by Beatley (1975) and Rickard and Beatley (1965). They referred to this community as transitional between Great Basin sagebrush scrub and Mojave Desert creosote bush scrub, lying on non-saline, gentle slopes at middle elevations of 1200–1500 m. Species richness exceeds that of shadscale and sagebrush communities, but is less than that of creosote bush scrub. Beatley (1975) wrote that the *Grayia-Lycium* community was restricted to southern Nevada.

Five of the eight leading dominants of Alabama Hills vegetation are typical associates or dominants of the *Grayia-Lycium* community (Table 1). Of the 11 species Rickard and Beatley (1965) reported for that community, 10 were found in the Alabama Hills, although their relative importances were not always comparable. Specifically, Alabama Hills vegetation showed less dominance by *Grayia, Lycium,* and *Eurotia,* and added three new elements: *Atriplex polycarpa, Haplopappus cooperi,* and *Eriogonum fasciculatum* subsp. *polifolium,* the first two being restricted in range to California.

Ordination. The polar ordination resulted in a wide dispersion of stands in two-dimensional space (Fig. 1), with little indication of clusters of stands. This may indicate that there are quite a few discrete habitats, each supporting its own community variant, and that the intensity of sampling was not sufficient to replicate these. Our limited environmental data, however, suggest that much of the horizontal and vertical spread can be correlated with geologic substrate and degree of present grazing intensity. Lightly grazed stands on granitic material

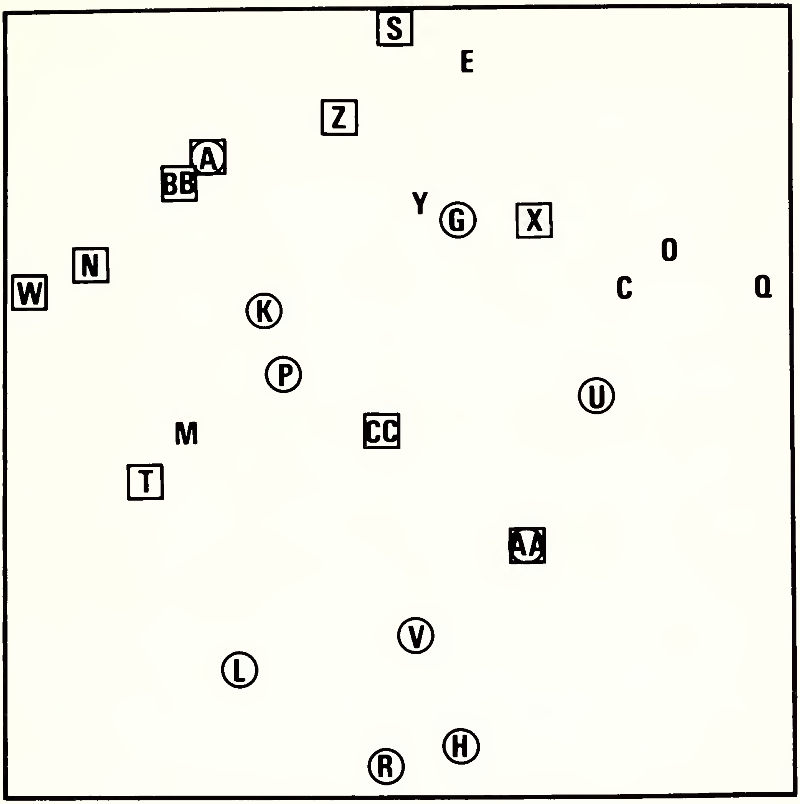

FIG. 1. Polar ordination of 24 stands. Stand names are coded by letters. Boxed stands are on metavolcanics, circled stands are moderately to heavily grazed, open stands are on granitics and are lightly grazed or ungrazed.

are largely in the upper right quadrant; heavily grazed stands are largely in the lower half of the figure; stands on metavolcanic material are largely in the upper left quadrant.

Topographic roughness may be secondarily important in determining community composition. For example, sites C, O, and Q on the right side of the figure are all on bouldery, uneven terrain that experiences shade at some time of the day or year. Mosses and lichens were common. Vascular dominants in those three sites were somewhat different from those shown in Table 1 for all sites: *Haplopappus cooperi, Ephedra viridis, Chrysothamnus teretifolius, Senecio douglasii,* and *Stephanomeria pauciflora*. It is possible that a careful consideration of other site features would also show some correlation with community variation, but we believe that the number of stands is currently too few to warrant such an analysis.

TABLE 2. AVERAGE DENSITY AND CANOPY VOLUME FOR SPECIES ON 10 "GRAZED" AND 14 "UNGRAZED" PLOTS. Relative values are not shown. Only species recorded on three or more grazed and three or more ungrazed plots are included. All volumes are approximated by a cone. One asterisk = statistically different at the 0.05 level, two asterisks = 0.01 level, three asterisks = 0.001 level, t-test.

Species	Density (plants/700 m^2)		Volume (dm^3/700 m^2)	
	Grazed	Ungrazed	Grazed	Ungrazed
Ambrosia dumosa	10*	113*	76*	644*
Artemisia spinescens	117	76	216	146
Atriplex confertifolia	132	164	1383	1532
Atriplex polycarpa	34	30	2873	1798
Chrysothamnus teretifolius	19	7	652	56
Ephedra nevadensis	52***	5***	3245**	507**
Eriogonum fasciculatum	80	114	434	1131
Eurotia lanata	37	33	160	162
Grayia spinosa	76	27	1963	1383
Gutierrezia microcephala	42	36	185	90
Haplopappus cooperi	275**	21**	1764**	277**
Hymenoclea salsola	115**	35**	1450	776
Lepidium fremontii	33	22	252	87
Lycium andersonii	30	11	1890	1182
Lycium cooperi	1	4	101	1439
Machaeranthera (Xylorhiza) tortifolia	21	54	50	87
Stephanomeria pauciflora	33**	98**	174*	857*
Total	1108	849	16,867	12,152

Effect of grazing. Our ordination indicated that grazing intensity by livestock is correlated with major stand-to-stand variation. While we cannot here demonstrate a causative relationship, vegetation in the Great Basin province in general has undergone much change over the past century due to over-grazing and the introduction of exotic, aggressive plant species (Young et al. 1972, 1975). Consequently, we analyzed species preference for "grazed" (heavily to moderately grazed, based on subjective criteria) and "ungrazed" (lightly grazed to ungrazed) plots in Table 2. Our 24 plots were nearly evenly divided between these two categories, 10 heavily to moderately grazed and 14 lightly grazed to ungrazed.

Of 17 taxa that occurred in at least six plots (three grazed, three ungrazed), only five showed statistically significant differences in absolute density and/or absolute canopy volume. Grazing appeared to depress *Ambrosia dumosa* 8–11-fold and *Stephanomeria pauciflora* 3–5-fold. Grazing appeared to stimulate *Ephedra nevadensis* 6–10-fold, *Haplopappus cooperi* 6–13-fold, and *Hymenoclea salsola* 2–3-fold. The relative canopy volume of *Lycium cooperi* was depressed 8-fold by grazing (0.05 level, not shown in Table 2). All other differences for absolute or relative values were statistically insignificant at the 0.05 confidence level. Surprisingly, total density and canopy volume were greater on grazed sites.

We must emphasis that the above differences have to be carefully interpreted, and their relationship to grazing is not absolutely clear. The history of grazing in the area during this century is complex, and grazing intensity may certainly have varied from site to site over time. Some sites may have been heavily grazed in the past to such an extent that species composition has not yet recovered, despite absence of grazing in recent decades. Some sites may be lightly grazed because of unique substrate or topographical features which make them inaccessible, but it is such physical features which promote or depress the cover of certain plant species and not the presence or absence of grazing.

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NOTEWORTHY COLLECTIONS

NEW MEXICO

ARENARIA STRICTA Michx. subsp. TEXANA (Robins.) Maguire (CARYOPHYLLACEAE).—Torrance Co., 2.1 km e. of Negra, rocky outcrop (T5N R13E S12), 1950 m, 6 Jun 1977, *Wagner & Sabo 3053* (RM, UNM) (Det. and confirmation of extension of extension by R. Hartman, RM, 1981).

Significance. First report for NM, range extension of at least 250 km from high plains of TX.

GALIUM EMERYENSE Demp. & Ehrend. subsp. EMERYENSE (RUBIACEAE).—San Juan Co., The Hogback, ca. 13 km e. of Shiprock and ca. 5 km nne. of Hwy 550 (T30N R16W S19), 1650 m, 13 May 1977, *Wagner & Sabo 2880* (UC) (Det. L. Dempster, UC, 1981).

Significance. First report for NM, range extension ca. 130 km se. from San Juan Co., Utah. This specimen is atypical in that it has leaves similar to *G. coloradoense* Wright, which presumably was involved in the formation of *G. emeryense* (Dempster, pers. comm. 1981).

LEPIDIUM OBLONGUM Small (BRASSICACAE).—Bernalillo Co., ne. of Pajarito on e. side of Rio Grande (T9N R2E S19), 15 Aug 1976, *Wagner & Cole 2349* (MO) (Det. R. Rollins, GH, 1981).

Significance. A range extension nw. from Chaves Co., NM, ca. 270 km.—WARREN L. WAGNER, Missouri Botanical Garden, PO Box 299, St. Louis 63166. (Received 14 May 1982)